TRANSLATION

THERMONUCLEAR WEAPONS

By M. B. Neyman and K. M. Sadilenko

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the temperature rise, the more easily will it be maintained, and the more powerful will be the action of the explosion.

For comparison, the Table also gives data on the fission of uranium and plutonium. The hydrogen isotopes H^1, H^2, and H^3 are denoted by H, D, and T.

Table 4

Characteristics of Certain Thermonuclear Reactions

No.	Nuclear Reaction	Thermal Effect in Thousand Million Calories per Gram-Atom	TNT Equivalent in Thousand Tons per 1 kg*	Energy Liberated by 1 kg of Substances Participating in the Reaction, in kcal	Duration of the Reaction at a Temperature of 20 Million Degrees
1	$H + H = D + {}_1\beta^0$	34	1,8	$1,66 \cdot 10^{10}$	10^{11} years
2	$H + D = {}_2He^3$	120	6,2	$3,9 \cdot 10^{10}$	0,5 sec
3	$H + T = {}_2He^4$	480	23,5	$11,7 \cdot 10^{10}$	0,05 sec
4	$D + D = {}_2He^3 + {}_0n^1$	79	3,9	$1,93 \cdot 10^{10}$	0,00003 sec
5	$D + D = H + T$	96	4,7	$2,35 \cdot 10^{10}$	0,00003 sec
6	$D + T = {}_2He^4 + {}_0n^1$	420	17,6	$8,2 \cdot 10^{10}$	0,000003 sec
7	$T + T = {}_2He^4 + 2{}_0n^1$	270	12,2	$4,4 \cdot 10^{10}$	—
8	${}_3Li^6 + D = 2{}_2He^4$	540	67	$1,2 \cdot 10^{10}$	—
9	${}_3Li^6 + T = 2{}_2He^4 + {}_0n^1$	380	42	$6.6 \cdot 10^{10}$	—
10	${}_3Li^7 + H = 2{}_2He^4$	410	51	$4,65 \cdot 10^{10}$	1 min
11	${}_5B^{11} + H = 3{}_2He^4$	190	9,2	$5,0 \cdot 10^{10}$	3 days
12	Fission of uranium or plutonium	4800	20	$2,0 \cdot 10^{10}$	—

*In the third column, the energy of reactions 1 - 7 is given in terms of the TNT equivalent per kilogram of explosive, based on the weights of heavy and superheavy water, instead of that of the free isotopes of hydrogen.

As will be seen from the Table, thermonuclear reactions differ greatly in their

Tritium

Superheavy hydrogen, or tritium, exists only in negligible amounts in nature. It is formed in the upper layers of the atmosphere under the action of cosmic rays.

The fundamental reaction of tritium formation is the reaction of fast cosmic neutrons with nitrogen:

$$_{7}N^{14} + {}_{0}n^{1} = {}_{6}C^{12} + {}_{1}H^{3}$$

Tritium, however, cannot accumulate in appreciable quantities, since it is a radioactive isotope with a half-life of 12.4 years. On disintegration, it emits a beta-particle and is transformed into helium:

$$_{1}H^{3} = {}_{2}He^{3} + {}_{-1}\beta^{0}$$

The artificial preparation of tritium is based on the reaction of slow neutrons with the nuclei of the light isotope of lithium $_{3}Li^{6}$:

$$_{3}Li^{6} + {}_{0}n^{1} = {}_{2}He^{4} + {}_{1}H^{3}$$

To prepare tritium in large amounts, natural lithium, which is a mixture of two isotopes, lithium-6 and lithium-7, is placed in a nuclear reactor instead of part of the shim rods. Under the action of slow neutrons, lithium-6 is transformed gradually into tritium and helium.

The tritium formed in the reactor is partially dissolved in the lithium, and forms a chemical compound - lithium hybride - in which an atom of tritium combines with an atom of lithium (LiT). It is very difficult to separate the tritium from lithium hydride, since this stable compound is decomposed with difficulty, even on strong heating. It is therefore disadvantageous to irradiate metallic lithium in the reactor. A lithium salt - lithium fluoride (LiF) - was formerly irradiated. Recently, alloys of lithium with magnesium, from which it is easier to separate the

tritium, are being used.

Tritium is a gas. For storage and use, it is usually converted into tritium water (T_2O) which is obtained by the combustion of tritium in oxygen or air.

The production of tritium in nuclear reactors involves a decrease in plutonium production, since the introduction of lithium with the object of producing tritium causes an additional consumption of nuclear fuel without a corresponding formation of plutonium. The production of 1 kg of tritium in a nuclear reactor involves a decrease of about 80 kg in its plutonium production. The production of tritium also results in an immense consumption of power and of the uranium raw material.

During the initial period of work on the creation of thermonuclear weapons in the United States, 1 kg of tritium cost 500 million dollars. To prepare 1 kg of tritium took 11 - 12 tons of metallic uranium. The daily production of 2 gm of tritium required 10 kg of uranium-235 and a 1-million-kw reactor. The immense plant producing tritium had to operate 2.5 years to produce the amount of tritium necessary for a single hydrogen bomb (obviously of the deuterium-tritium type). The production of tritium today is considerably less expensive. But even today in the United States tritium is still thousands of times as expensive as gaseous deuterium, and still costs hundreds of thousands of dollars per kilogram.

Deuterium

Natural water, in which the hydrogen usually contains 0.014% of deuterium, is the most convenient raw material for deuterium production. Water is readily available, and its supply is practically inexhaustible.

The production of deuterium in the pure form involves the necessity of separating the hydrogen isotopes.

It is incomparably simpler to separate the hydrogen isotopes than to separate the isotopes of other elements. Indeed, deuterium is twice as heavy as ordinary hydrogen, while, for example, the difference in the weight of the uranium isotopes

U^{238} and U^{235} is less than 1.3%. For this reason, a number of physical properties (density, thermal conductivity, etc.) of compounds of heavy and light hydrogen differ appreciably, while there are practically no such differences between the compounds of the two uranium isotopes. For example, the density of heavy water, D_2O, is 1.1079 gm/cc, and it boils at 101.42°C and freezes at 3.802°C.

Such differences in properties make it relatively simple to separate heavy water from ordinary water by distillation (on account of the difference in the boiling points) and also by electrolysis. Thus, deuterium can be separated from water in the concentrated form by various methods.

The method developed first was based on the decomposition of water by an electric current. Everyone knows that water in this case is dissociated into hydrogen and oxygen. Experiments showed that ordinary water, H_2O, was decomposed far more readily by the electric current than heavy water, D_2O. For this reason, the deuterium content of the hydrogen liberated by electrolysis is about 5 times less than its relative abundance in the water being decomposed.

It is clear that the undecomposed water, after electrolysis, will be more and more enriched in deuterium. This method permits ultimately to obtain a water in which the hydrogen contains over 99% of deuterium and only about 1% of ordinary hydrogen. This method of producing heavy water can be used only in countries and regions producing large amounts of electric power at low cost.

The second method is based on the fact that the boiling point of ordinary water is somewhat lower than that of heavy water. Light water can therefore be separated from heavy water by repeated distillation. In this way, at experimental plants, the deuterium content in the hydrogen of water could be increased from 0.014% to 88 - 92%. Electrolysis is more expedient for further concentrating the deuterium.

An advantage of the distillation method is the possibility of producing larger quantities of deuterium, as well as the simplicity of the equipment. A shortcoming, however, of the method is its cost, since the repeated evaporation of large quan-

tities of water requires vast amounts of heat.

The methods of very low-temperature distillation of hydrogen obtained from water, and containing 0.014% of deuterium, have also proved economically disadvantageous.

The most expedient method of preparing deuterium was found the chemical method. This method is based on the fact that deuterium in gaseous hydrogen, where its atoms are paired with protium atoms, tends to combine with oxygen and pass into water (HDO) over the reaction

$$HD + H_2O = H_2 + HDO$$

This reaction proceeds most rapidly at 500°C and, in the presence of catalysts*, even at 100°C.

The catalyst used for this purpose may be metallic palladium or platinum applied to charcoal, or nickel with chromium oxide.

Figure 22 is a schematic diagram of the industrial plant for preparing deuterium-enriched water. Steam is mixed with hydrogen and enters the first column, which contains layers of catalyst. Passing through the column, the water becomes gradually enriched in deuterium. The hydrogen in the steam entering the column contains 0.014% of deuterium, while in the discharged steam it contains 0.02% (in the sketch, the percentage of deuterium in the water in all cases relates to the hydrogen of the water).

The deuterium abundance of the hydrogen is correspondingly decreased: the intake hydrogen contains 0.01%, while the discharge hydrogen contains 0.005% of deuterium. The steam leaving the column is separated from the hydrogen by the cooler (3), liquid water being formed in the condenser while the hydrogen escapes. The water then enters the boiler (4), where it is evaporated, and then is fed to the second

*Substances which, without themselves undergoing change, will change the speed of a chemical process are called catalysts.

column. Here it is mixed with hydrogen containing 0.03% of deuterium. As a result of the reaction, the hydrogen of the water is now enriched with deuterium to 0.04%,

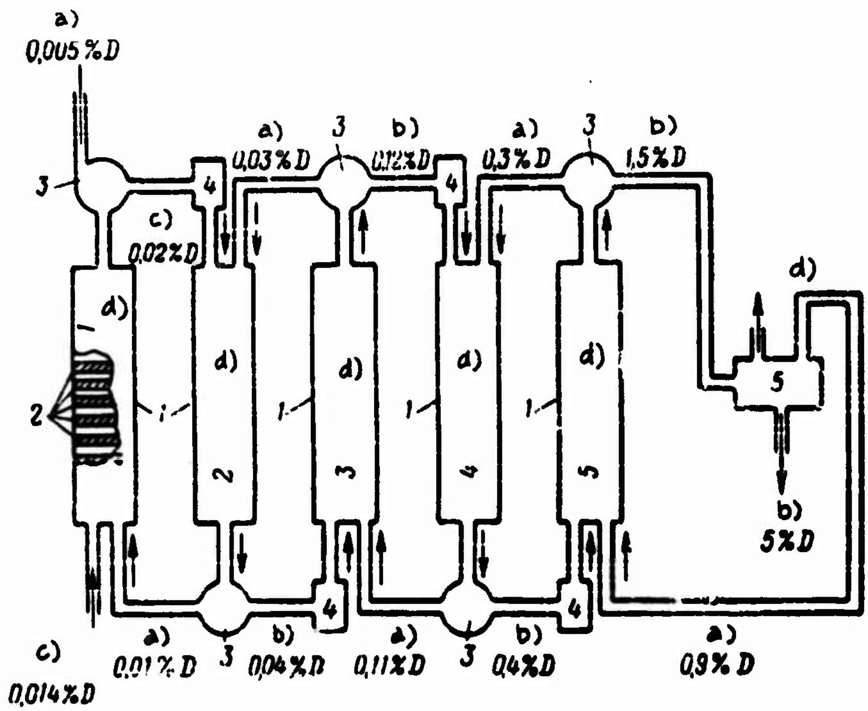

Fig.22 - Installation for the Preparation of Deuterium-Enriched Water

1 - Exchange column; 2 - Catalyst layers; 3 - Coolers; 4 - Boilers; 5 - Electrolyzer

a) Hydrogen; b) Water; c) Water vapor; d) Oxygen

while the deuterium content in the free hydrogen decreases. The process of enriching the water with deuterium is repeated in the third, fourth, and fifth columns as shown in the sketch. The water leaving the fifth column contains 1.5% of deuterium. This water is then routed to the electrolyzer (5), in which the deuterium content in the hydrogen of the water is brought to 5%. Further concentration of the deuterium is accomplished at the electrolysis plant by the above method.

This chemical method of producing heavy water and deuterium is today the most

advantageous. Thanks to the large number of scientific studies on the separation of deuterium in the USSR, the United States, and other countries, the cost of deuterium production has considerably declined during recent years. According to the American literature, 1 kg of heavy water cost about $5000 at the beginning of the first tests of thermonuclear weapons. Today it costs considerably less. According to the literature, 1 kg of heavy water today costs about $200, and 1 kg of gaseous deuterium about $1000.

Lithium

Lithium is a silvery white metal, usually with a yellowish tinge if impurities are present. It is characterized by low specific gravity (0.53), low hardness, low melting point (186°C), low boiling point, and high electric conductivity. Lithium is an active element. It combines with oxygen and nitrogen at room temperature, and with hydrogen on heating. It dissolves readily in acids and violently decomposes water under evolution of hydrogen.

In recent years, lithium has become highly important in atomic technology. A few years ago, the world production of lithium compounds was very small. These were used in the manufacture of certain ceramic wares, to improve the properties of lubricating oils, in preparing the flux used in aluminum welding, in the manufacture of alkaline storage batteries and dry batteries, and, in small amounts, in metallurgy, to remove gases dissolved in metals. About 3000 tons of lithium carbonate were used annually in the United States for all these purposes.

In 1955 - 1956 the production of lithium carbonate in the United States increased to 20,000 tons a year, of which 17,000 tons were purchased by the United States government for secret purposes, obviously for the production of tritium and lithium thermonuclear weapons. Over 100 tons of metallic lithium-6 can be separated from 17,000 tons of lithium carbonate.

The most widely distributed natural minerals containing lithium are spodumene

($Li_2O \cdot Al_2O_3 \cdot 4SiO_2$) and lepidolite ($LiF \cdot KF \cdot Al_2O_3 \cdot 3SiO_2$). The richest deposits of these minerals are located in Rhodesia, Canada, and the United States.

Two processes are used today for separating lithium from its ores.

The first process consists in fusing the lithium minerals with lime, thus forming caustic lithia (LiOH). Large amounts of materials must be processed in rotary kilns, but on the other hand the raw material used (lime) is relatively cheap.

The second process is based on roasting lithium minerals at 1100°C, followed by treatment of the product with concentrated sulfuric acid. The lithium sulfate obtained is dissolved in water. Treatment with soda yields the water-insoluble lithium carbonate. This method is less cumbersome than the former but is more complicated, and a more valuable raw material must be used.

The lithium compounds prepared by the above methods can easily be converted into the salt LiCl, which melts on heating and is decomposed by an electric current into metallic lithium and chlorine.

Metallic lithium contains 92.6% of the isotope $_3Li^7$ and 7.4% of the isotope $_3Li^6$. The same methods used to separate hydrogen isotopes may be used to separate lithium isotopes: the electrolytic method, the distillation method, and the chemical exchange method.

Lithium isotopes may also be separated by the electromagnetic method. This is based on separating a beam of fast lithium ions, under the action of a magnetic field, into two beams, one containing $_3Li^6$ ions and the other the heavier $_3Li^7$ ions. The literature describes no practically useful methods of separating lithium isotopes.

Detection of Atomic and Thermonuclear Explosions

There are well-developed methods today which permit the easy detection of an explosion, determination of the place and time of the explosion, and the type of bomb exploded, at any point of the globe.

Up to now there has not been a single case in which explosions of atomic or hydrogen bombs were not detected by the aid of suitable scientific and technical means. The development of nuclear physics and of the atomic industry is inseparably linked to the improvement of technique and instrumentation, permitting a reliable detection of explosions of nuclear weapons at a distance.

According to the literature data, the occurrence of an atomic or thermonuclear explosion can be established by the generally adopted method of tracing all types of significant tremors of the earth's crust (earthquakes, seaquakes, powerful explosions). This method is adopted in seismology (the science of oscillations in the earth's crust) and is effected by means of seismographs, which are instruments detecting tremors of the earth's crust. A seismograph indicates the force and direction of propagation of tremors. Owing to the nonuniform rate of propagation of the transverse and longitudinal oscillations of the earth's crust arising during an explosion, the readings of a single seismograph are sufficient to determine the epicenter of the explosion.

Detailed information about an atomic explosion may also be obtained by a study of the atmospheric radioactivity.

The literature states that aircraft, specially equipped with air-sampling instruments, are used to study the atmospheric radioactivity in atomic explosions. Such an instrument (a sampler), which is schematically shown in Fig.40, may be placed, for example, in the aircraft wing. In his cockpit, the pilot opens the stopper of the wing sampler at the required time by means of a lever or other device. The air enters the sampler and passes through filters which retain the dust.

Here the dust particles of plutonium, uranium-235, and the fissioned "debris" formed during the chain reaction of the explosion are retained. In the next part of the instrument, filled with a solution of alkali, the carbon dioxide gas, which may con-

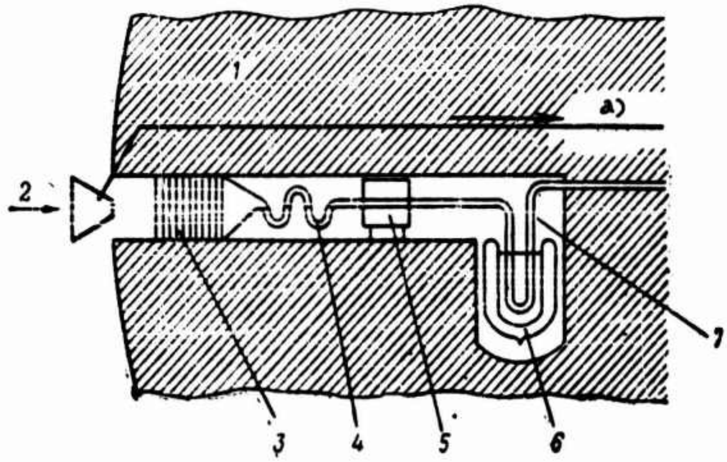

Fig.40 - Possible Schematic Diagram of Aircraft Air Analyzer

1 - Aircraft wing; 2 - Stopper of sampler; 3 - Filter absorbing the plutonium, uranium-235, and fission "debris"; 4 - Carbon dioxide absorbers; 5 - Miniature stove; 6 - Dewar vessel with liquid air; 7 - Tube for freezing water

a) To aircraft cockpit

tain radioactive carbon formed during the explosion, is absorbed. In the next unit of the analyzer, which is a miniature stove, the tritium contained in the sample is burned, forming tritium water which is condensed in the cooler. The more detailed separation of the substances trapped by the gas analyzer, and their analysis, is accomplished later at special laboratories.

The filters are first examined at the laboratory. From the composition of the substances caught by the filter, one may judge the character of the explosion.

The contents of the alkali absorbers and of the water frozen in the analyzer are then investigated. If radioactive carbon dioxide is detected in the alkali absorbers, and the water contains tritium, there is every reason to suppose that a

thermonuclear bomb has been exploded somewhere.

In examining the filters of the analyzer, besides plutonium and uranium, one may also detect fission "fragments" which differ in their half-lives and in their chemical properties.

In 1954, after several tests of thermonuclear weapons, scientists in Japan and other countries took many air samples at great altitudes. In these samples they detected, by this method, the radioactive isotopes: strontium-90, zirconium-95, barium-140, lanthanum-140, yttrium-91, cerium-141, and other fission "debris" of uranium and plutonium. The number of these isotopes proves to be so great that their origin could not be explained by the explosion of atomic detonators. The conclusion was therefore drawn that these "fragments" had been formed as a result of the fission of a heavy uranium casing of powerful thermonuclear bombs of a new type. A number of scientists assumed that in this case explosions of thermonuclear bombs took place, and the term three-phase bombs was proposed for them.

A problem no less important than the determination of the type of the exploded bomb is the determination of the time of explosion. This problem can be solved by the collection of radioactive explosion products on a paper filter by means of the above-described instrument, and observing the decay of their radioactivity with time.

Table 10 shows the decay of the radioactivity with time, taking the radioactivity 1 hr after the explosion as unity.

Table 10

Variation in Radioactivity of Fission "Fragments" with Time

Time in Hours	1	25	50	75	100	125	150	175	200
Radioactivity in arbitrary units	1	0,021	0,0091	0,0059	0,004	0,003	0,0024	0,0020	0,0017

It will be seen from this Table that the radioactivity had fallen, within 25 hrs after the explosion, to almost one fiftieth of its value 1 hr after the explosion. During the following 25 hrs, the radioactivity decreased still further by a factor of 0.021:0.0091 = 2.3. In the same way we may find how many times the radioactivity decreases during each succeeding 25-hr period.

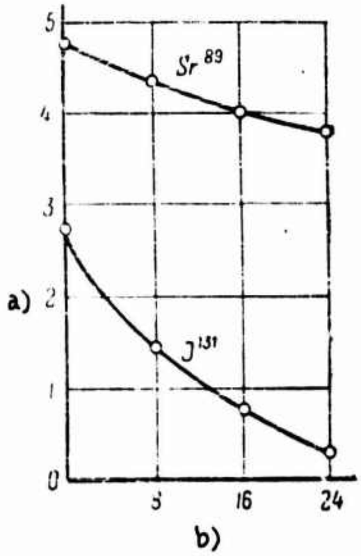

Fig.41 - Radiation of Strontium-89 and Iodine-131 Content of the "Fragments", Against Time Elapsed after Explosion of a Nuclear Bomb

a) % in fission "debris"; b) Time in days

Knowing how the radioactivity of the dust varies with time, the instant of explosion can be determined.

A somewhat different method of determining the time of explosion of a thermonuclear bomb is based on the fact that the different fission "fragments" of uranium and plutonium decay at different rates. Thus, for instance, one of the "fragments", strontium-89, has a half-life of 54.5 days, while another, iodine-131, has a half-life of 8 days. Figure 41 shows the curves of the decline in the content of these isotopes in the "fragments" with the passage of time. At the instant of the explosion, strontium-89 composes 4.6% of the fission "fragments", and iodine-131, 2.8%. About 24 days after the explosion, the content of these isotopes had fallen respectively to 3.7 and 0.4%.

If the strontium-89 and iodine-131 are separated by chemical methods from the "fragments", and the activity of each of these isotopes is separately measured, it will be easy to calculate the ratio of their activities at various periods after the explosion. Table 11 gives the results of such calculations.

It will be clear from the Table that this ratio, which is 0.23 at the instant

of explosion, gradually increases and becomes 4.3 forty days after the explosion. By experimental determination of the ratio of activity of strontium and iodine, isolated from the dust collected after the explosion, it is easy to establish the time

Table 11

Ratio of Activities of Sr^{89} and I^{131} in Air, as a Function of Elapsed Time since Explosion

Time since Explosion, in Days	0	8	16	24	40
Ratio of activities of Sr^{89} and I^{131}	0,23	0,44	0,8	1,5	4,3

of explosion. The same calculation may be performed, using a determination of the activities of any other pair of "fragments" with different half-lives.

The radioactive cloud formed as a result of an atomic explosion remains in the troposphere and is carried off by the wind. By taking air samples at great altitudes and finding the products of the atomic explosion, one may approximately determine the site of the explosion, if meteorological data on speed and direction of the wind are available. Of course, to solve this problem, one must first determine the instant of explosion.

Figure 42 schematically shows the direction of motion of the air masses at altitudes of 10 - 12 km. If an air sample was taken at point (1) and if analyses have shown that the explosion (for instance) occurred 8 days previously, then the region of explosion (2) can be determined, provided, of course, that we know not only the direction but also the speed of the wind.

A rapid determination of the site of explosion of a nuclear bomb dropped by the enemy is also very important, especially for a rapid determination of the localities of possible damage and for better organization of the rescue operations. For this reason, one must be able to determine the site of an explosion at a considerable

distance. From information in the foreign literature, simple instruments resembling sundials may be used for this purpose. One such instrument is shown in Fig.43.

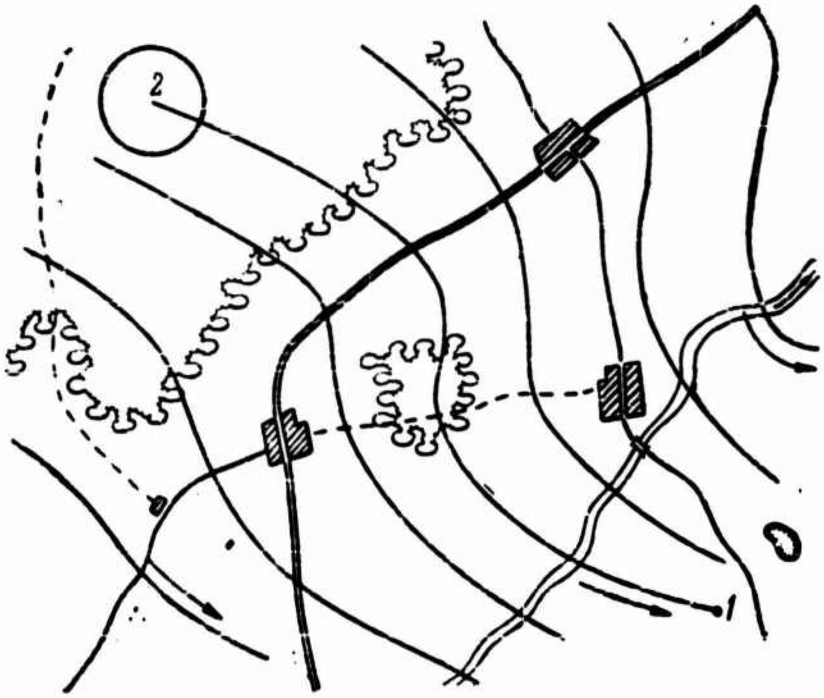

Fig.42 - Schematic Diagram of Motion of Air Masses:

1 - Place of air sampling; 2 - Region of explosion

This device is a square metal plate with a vertical rod at the center. A circular scale is placed around the rod. The surface of the instrument is coated with a paint which changes color on heating. Such instruments are placed in areas where there is danger that a nuclear bomb will be dropped.

After a nuclear explosion, the heat rays, striking the surface of the instrument, change the color of the heat-sensitive paint everywhere except in the places covered by the shadow of the rod. A print of the shadow of the rod is obtained, from which the direction of the explosion site is easily determined. If one has readings of at least two such instruments, the site of the explosion is determined

by the intersection of the lines giving the respective direction of the site of explosion from each instrument.

Thermonuclear Weapons Testing

At the end of World War II, Oppenheimer proposed the utilization of thermonuclear reactions for powerful bombs. But the experiments then conducted in the United States ended in failure. This work was resumed in 1950.

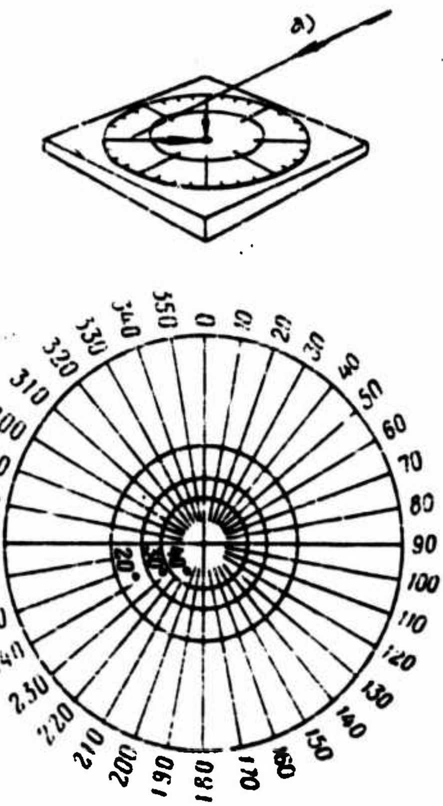

Fig.43 - "Sundial" Type Instrument

a) Direction of rays

For the laborious calculations of the probability of various thermonuclear reactions, modern electronic computers were then used for the first time. It is well known that computers operate at such speed that a single machine can replace hundreds of qualified mathematicians. The calculations performed by the aid of these computers showed that, at the temperature of explosion of a plutonium bomb, a thermonuclear reaction in a mixture of deuterium and tritium could commence. To verify these conclusions, a small amount of tritium and deuterium was prepared, and a mixture of them was introduced into a plutonium bomb. The bomb was exploded at the end of 1951 in one of the test fields of the United States. Careful measurements showed that the number of neutrons formed on explosion of the bomb was somewhat in excess of the number of neutrons formed on

explosion of an atomic bomb. This fact could be explained only if the tritium and deuterium had actually entered partially into a thermonuclear reaction during the explosion, forming helium and neutrons. After experiments, the work on tritium production was speeded up in the United States, and in November 1952, in the Pacific Ocean on Eniwetok, one of the small islands of the Marshall group, the first large-scale experimental thermonuclear explosions were carried out.

According to the foreign literature, it was only in this first thermonuclear explosion in November 1952 that the reaction between tritium and deuterium was utilized. It was really not a bomb at all that was set off, but a specially constructed installation on the ground, weighing 62 tons. The deuterium and tritium were employed in this installation either in the form of compressed gases or in the form of water. As for the thermonuclear explosions staged somewhat later by the Americans in the spring of 1954, according to the literature, these were already explosions of bombs that did not contain tritium introduced from outside, but were filled instead with lithium deuteride. It is therefore possible that a hydrogen bomb need contain only an atomic detonator and lithium deuteride. During the first stage of the explosion, the presence of neutrons assures the formation of tritium and its interaction with the deuterium. This causes a sharp temperature rise (according to the literature data, to tens of millions of degrees), so that a direct interaction between lithium and deuterium now proves possible.

According to data in the foreign literature, a great funnel was formed during the thermonuclear explosion on Eniwetok Island in 1952. The diameter of the fire ball was about 3 - 5 km, and the intense glow lasted 4 sec. The radioactive cloud reached an altitude of 30 km in 10 min.

In autumn 1953, as stated by a Tass report, a powerful thermonuclear weapon, consisting of a thermonuclear bomb, was tested in the USSR.

At the beginning of 1954, when the whole world was waiting for the Geneva conference, the United States staged a series of thermonuclear explosions on Bikini

Island in the Pacific Ocean (Fig.44). These included explosions of bombs with a TNT equivalent of several million tons. A hydrogen-uranium (three-phase) bomb is believed to have been exploded on 1 March 1954.

The United States press advertised these explosions in every possible way. They wrote much about the destruction caused by these explosions and asserted that

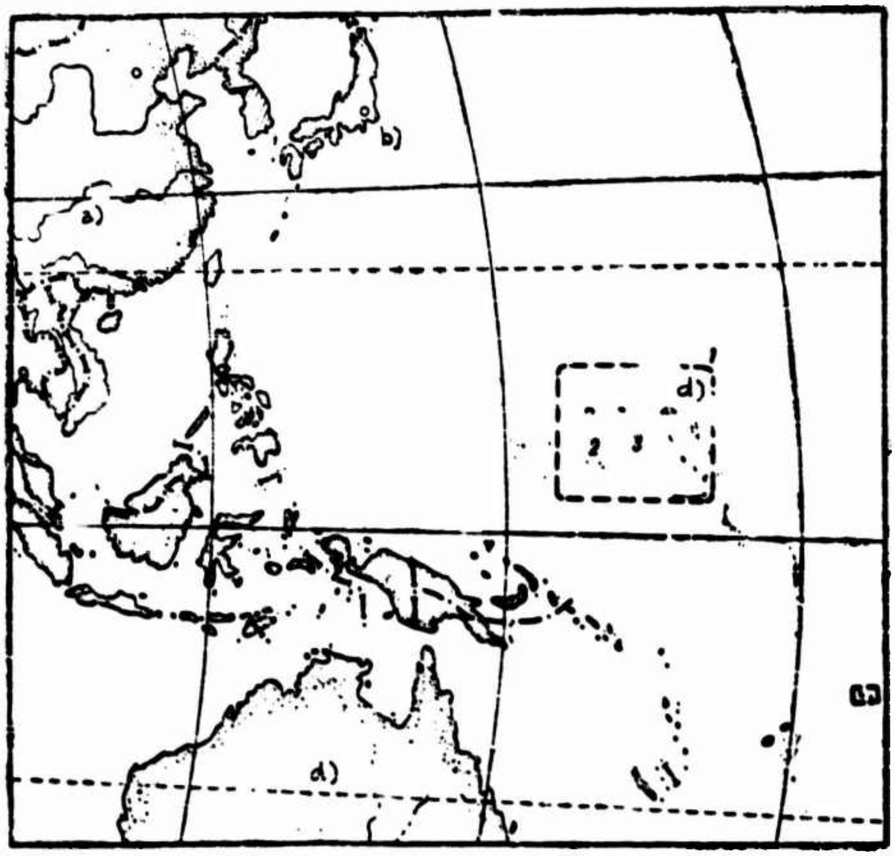

Fig.44 - Map of Region of Pacific Ocean

1 - Test zone for United States nuclear weapons; 2 - Eniwetok atoll; 3 - Bikini atoll

a) China; b) Japan; c) Australia; d) Marshall Islands

the ocean water had been involved in thermonuclear reactions under the influence of the high temperatures developed in these explosions. The newspapers claimed that the

explosive force, alleged to have been measured in these experiments, was about five times as great as the calculations.

Such reports, of course, do not correspond to reality. Obviously, at the temperature reached during the tests and, consequently, also reached by that part of the bomb material that has time to enter into reaction before being dissipated, the force was greater than expected, i.e., the coefficient of utilization factor of the charge was higher than expected, but, of course, it could not have exceeded it by 100%.

In the explosion of hydrogen bombs charged with lithium hydride, and a fortiori, with deuterium and tritium, as stated, temperatures are developed at which thermonuclear reactions with the participation of hydrogen and oxygen cannot proceed at explosive speed, i.e., such heavy nuclei will not enter into reaction. To "ignite" such mixtures during the millionths of a second that the high temperature of the hydrogen bomb explosion lasts, would demand superhigh temperatures that could not be provided by any thermonuclear reaction whatever. There is, therefore, no reason to fear that water or soil can enter into a chain or thermonuclear transformation. The destructive force of any bomb is limited to its own specially prepared contents. Obviously, the exaggerated data published in the United States on the power of thermonuclear explosions were based on incorrect calculations.

The literature contains statements to the effect that Soviet workers have attained such success in the production of hydrogen weapons that it was not the Soviet Union that was in the position of backward countries, but the United States.

In recent years, in accordance with the research plan in atomic energy, new types of thermonuclear weapons have been tested in the USSR. The explosions of thermonuclear bombs were the most powerful of all explosions ever staged. A powerful thermonuclear bomb was dropped from an aircraft in November 1955 and exploded at a great altitude. The explosion was staged at a great altitude with the object of avoiding radioactive effects.

These tests completely justified the corresponding research calculations. They also showed important new achievements of Soviet scientists and engineers. Our scientists and engineers succeeded, with the relatively small amount of nuclear materials used, in obtaining an explosion of a force equal to that of several megatons of conventional explosive.

These tests, in which a thermonuclear bomb was first dropped from an aircraft, showed that the Soviet Union continues to move ahead of the United States in this field of military technology. It was May 1956 before the first tests in the United States on dropping of a thermonuclear bomb from an aircraft and its explosion in the air.

In order to develop and improve thermonuclear weapons and means of protection against them, test explosions have been periodically staged. In the USSR, atomic and nuclear weapons have been tested in accordance with the plan for research and experimental work in atomic energy. These tests have the object of improving atomic and thermonuclear weapons and developing powerful atomic and hydrogen charges of new design for the armament of various sectors of the military forces. Extensive research has been staged, in this connection, on problems of the protection of humans. In order to ensure the safety of the population and of the test personnel, tests have as a rule been staged at great altitudes, a fact which has sharply decreased the radioactive fallout.

How and where have tests of atomic and thermonuclear bombs been staged?

According to the foreign literature, atomic and thermonuclear bombs have been tested at special fields remote from populated points. Such proving grounds are usually located in valleys surrounded by hills, in deserts, or on small islands far from the continents.

If the action of the explosion is to be tested in the air, the bomb is dropped from an aircraft; for a ground explosion, a steel tower up to 100 m in height is erected on the test site. On the top of this tower, the atomic or hydrogen bomb is

placed, with lines running from it to the command point, at a distance of 10 - 30 km from the tower. This command point is placed in a special concrete bunker. Objects, on which the action of the explosion is to be studied, are placed around the tower at various distances from it. Figure 45 is a schematic diagram of one such test of an atomic bomb.

For this test, standard stuccoed frame houses were built at a distance of 1 - 2 km from the tower. Automobiles filled with gasoline and oil were placed at

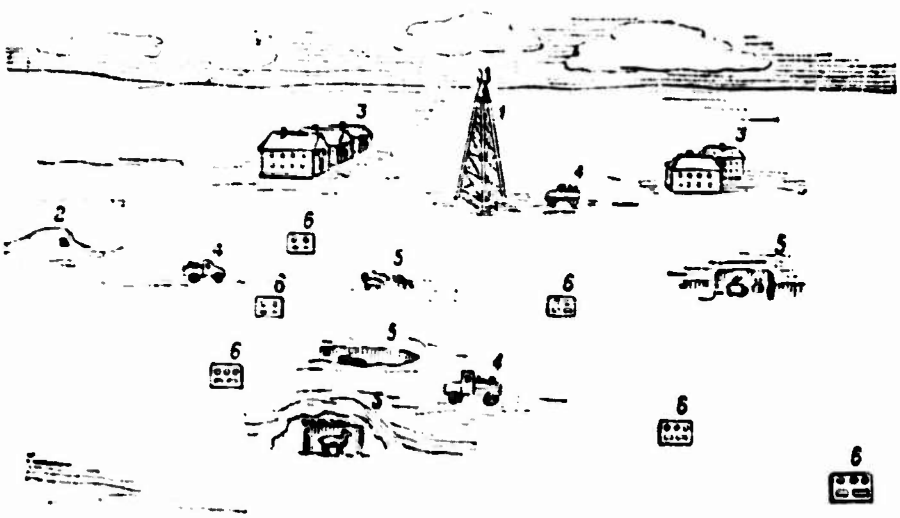

Fig.45 - Possible Version of Proving Ground for Atomic and Thermonuclear Weapons

1 - Site of explosion; 2 - Command point; 3 - Standard houses; 4 - Automobiles with manikins and instruments; 5 - Experimental animals; 6 - Instruments for measuring flash, flux of fast and slow neutrons, shock waves, gamma-radiations, etc.

various distances from the tower. Manikins dressed in clothing of various materials were placed in the houses and in several automobiles (Fig.45). Experimental animals, dogs, goats, rabbits, rats, etc. were placed on the ground and in earthwork bunkers. Various instruments for measuring the temperature, the flux of radiant energy, the number of neutrons, the pressure of the shock wave and other factors were placed at

many points on the surface of the ground, on the walls of the houses, in the rooms, on the automobiles and on the manikins.

When all preparations for the tests are completed, the explosion of the atomic or thermonuclear bomb takes place at a predetermined time. Since the temperature of the explosion reaches several million degrees, the flash is considerably brighter than the sun; for this reason the eyes of all observers must be protected by special black goggles.

Atomic explosions are photographed, and motion pictures taken, at safe distances, from the ground (or water) and from the air. Radio-controlled aircraft with

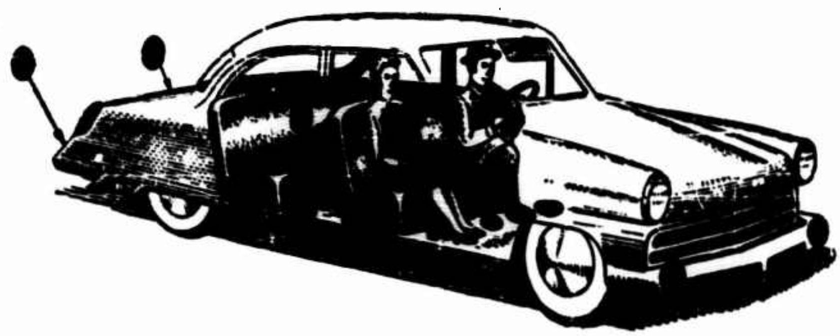

Fig.46 - Automobiles with Manikins. The black circles indicate the location of instruments for measuring power of the shock wave, temperature, neutron flux, luminous and gamma-radiation

automatic motion-picture and still cameras are used for short-range aerial photography.

Figure 47 shows a series of consecutive photographs of a two-story house at a distance of 1 km from the site of explosion of an atomic bomb with a TNT equivalent of the order of 20,000 tons.

The first picture (a) was taken 0.01 sec before the explosion. The second picture (b) was taken 0.03 sec after the atomic blast. It will be clearly seen that the paint that had covered the plaster on the wall facing the tower began to smoke and burst into flame. In another 0.03 sec, the tar that had covered the roof also

began to ignite, as will be seen in the photo (c). Soon the shock wave reached the house, which burst into flame and began structurally to disintegrate: photo (d). The last photograph (e), taken 10 sec after the explosion, shows the house collapsed by the shock wave. The wooden beams and boards which, at the instant of explosion,

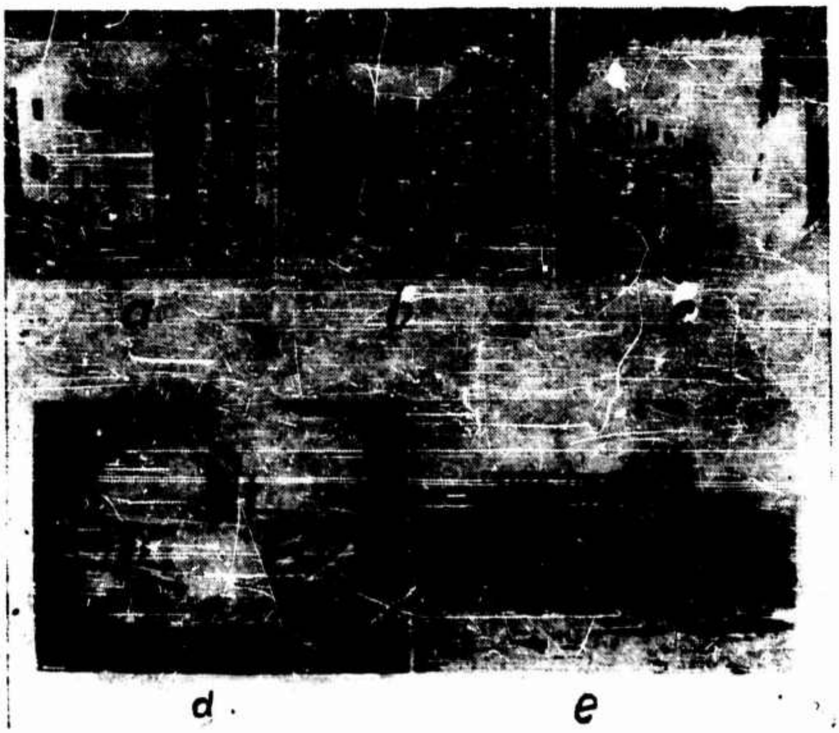

Fig.47 - Stages of Destruction of a Two-Story House by Nuclear Blast

had been protected by a thin layer of plaster, remained entirely uncharred. The manikins inside the house were likewise entirely unaffected by the thermal radiation, they had been reliably protected by the relatively thin plastered wooden wall.

Automobiles at distances of 500 - 1800 m from the site of explosion were affected to a varying degree. The paint was scorched, and many suffered mechanical damage. Automobiles farther than 800 m away were less affected. Some automobiles could be driven away soon after the explosion.

The animals on the ground at distances up to 800 m suffered greatly, and many

of them died. The surviving animals were affected by radiation sickness in severe form and died 1 - 4 weeks after the explosion, while those in shelters at a depth of 1 - 2 m underground at a distance of 500 - 800 m from the explosion site showed almost no damage. Animals in shelters at distances of 800 - 1000 m did not suffer at all.

How is the utilization factor of nuclear fuel in atomic and hydrogen bombs determined? According to the literature, this problem can be solved during an atomic bomb test, for example, by sampling the air from the cloud formed after the explosion. This sample is then analyzed for plutonium, barium, and iodine. Barium and iodine are necessary fission products of plutonium. It is simpler to determine these than the other fission products. Knowing that the total barium and iodine amount to 3 - 4% of the weight of the fissioned plutonium, the amount of plutonium that has time to undergo fission is calculated. Since the amount of unfissioned plutonium is also determined by the analysis, one can approximately calculate the percentage of the plutonium that has fissioned and, consequently, the utilization factor for the nuclear fuel.

In the case of a thermonuclear bomb, the same method may be used, but, depending on the type of bomb, the substances characteristic of the thermonuclear explosion must be determined in the sample, for example, lithium and helium.

An interesting experiment was performed in one of the hydrogen bomb tests. It is desirable to use neutron beams of maximum power for the artificial production of new transuranium elements by neutron irradiation of uranium. The scientists decided to use the powerful neutron flux formed on explosion of a hydrogen bomb to irradiate heavy atoms. For this purpose, several kilograms of uranium were buried in the ground in the blast area of the hydrogen bomb, in such a way that the material was irradiated by the neutrons without being scattered by the shock wave. The experiments were successful, and the calculations were substantiated. It was presumed in this way that the transuranium elements 99 and 100, einsteinium and fermium, were first obtained.